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PATENT SPECIFICATION

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(54) IMPROVEMENTS IN ALUMINIUM ALLOYS AND TO SHAPED BODIES AND METHODS OF MAKING THEM FROM SUCH ALLOYS

(71) We, RIKEN LIGHT METAL INDUSTRY CO., LTD., a Japanese Company of No. 2-1, 3-chome, Magikane, Shizuoka-Shi, Shizuoka-Ken, Japan, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

This invention relates to aluminium alloys and to shaped bodies and methods of making them from such alloys. The invention is particularly concerned with the ageing of such alloys and of shaped bodies made therefrom.

An age hardening aluminium alloy has recently been developed, mechanical properties of which compare favourably with those of steel or like materials and which is lightweight, highly anti-corrosive and small in deformation resistance. Accordingly, it is used for various purposes, in particular, widely used for construction materials. The aluminium alloy shaped bodies, hereinafter called shapes, now used for construction materials are marketed after being coated with paint.

A conventional method of making aluminium alloy shapes is as follows:—

As illustrated in the chart shown in Figure 1 of the accompanying drawings, the manufacture starts with homogenization treatment of a cast ingot of aluminium alloy, for example, at 550°C for 2 to 3 hours. The cast ingot is then preheated, for example, at 400 to 500°C for 5 to 10 minutes and is formed by extrusion to a predetermined shape.

Next, the extruded shapes of the predetermined shape thus obtained are heated at

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205°C ± 5°C for 60 minutes to cause ageing to proceed. Thereafter, the extruded shapes are subjected to oxide film forming, coating, coated film curing and hardening and like treatments to provide the finished aluminium alloy shapes. 40

In the conventional manufacturing method, however, substantially no consideration is paid to economy of energy and simplification of the manufacturing processes, so that there are many problems to be solved. To overcome such problems, the inventors of the present invention have now devised a method, as illustrated in the chart shown in Figure 2 of the accompanying drawing, in which the extruded shapes are immediately subjected to oxide film formation and coating treatments without artificially expediting ageing of the aluminium alloy and are then heat-treated to thereby effect curing and hardening of the coated film and, also, ageing. 45 50 55 60

With this manufacturing method, oxide film formation, coating and other treatments are achieved before ageing of the aluminium alloy, so that these treatments can be easily performed and all the processes from extrusion forming to coating can be arranged as a continuous system. Further, since ageing is caused to proceed simultaneously with the curing and hardening of the coating, a separate heat treatment for ageing can be saved, which accomplishes an economy of energy and, also, ensures good adherence of the coated film with the shapes. 65 70 75

However, the manufacturing method illustrated in Figure 2 makes it necessary that the condition for ageing of the aluminium alloy and that for curing and hardening of

the coated film are substantially coincident with each other. It is very difficult to satisfy this requirement on an industrial scale.

An aluminium alloy commercially known under the name of A.A6063 is most widely used as a construction material. This aluminium alloy is a typical age hardening alloy and an excellent alloy such that when it is in the state of a cast ingot, it can be given a required extrusion capability by homogenization treatment and preheat treatment, and ageing can be brought about by subsequent heating to provide the desired mechanical characteristics. Further, this alloy contains 0.52% of magnesium and 0.45% of silicon, and is only commercially available with these amounts of alloying elements. In the case of this alloy, the extrusion capability is not impaired when it is heat-treated at $205^{\circ}\text{C} \pm 5^{\circ}\text{C}$ for 60 minutes and with the heat treatment ageing properly proceeds to provide predetermined mechanical properties. However, if the conditions for ageing are altered, that is, if the time for ageing is shortened and if the ageing temperature is lowered, the predetermined mechanical properties cannot be obtained.

Accordingly, in the case where the coated oxide film curing and hardening treatment and the ageing treatment are made coincident with each other in this conventional alloy, if no special paint is used for the coating it is required to lower the heating temperature and unnecessarily lengthen the heat treatment time so as not to deteriorate properties of the coated film. However, this brings about unfavourable results.

On the other hand, it is considered possible that if a special paint suitable to withstand the ageing conditions of the conventional alloy is employed, the coated film printing and hardening and the age hardening of the alloy can be achieved at the same time. However, it is technically difficult to raise only the printing and hardening temperature, for example, up to $205^{\circ}\text{C} \pm 5^{\circ}\text{C}$ without impairing the water solubility of the paint which is the most suitable for dip coating. Even when this problem is technically solved, the special paint must contain an expensive composition, and hence is very costly.

Further, considering the ageing conditions of the conventional alloy from the viewpoint of energy, the ageing temperature of $205^{\circ}\text{C} \pm 5^{\circ}\text{C}$ is too high and it is desirable to lower the temperature, and the ageing time of 60 minutes is also too long and it is preferred to shorten this time.

The aim of this invention is to provide an aluminium alloy of a composition which enables sufficient ageing of the alloy to be effected by heating it at a temperature of not more than 200°C for from 20 to 50 minutes, and to provide a method of making

aluminium alloy shapes by subjecting an aluminium alloy of such composition to casting, extrusion forming and surface treatment.

According to the present invention, an aluminium alloy consists by weight of 0.65% to 0.75% magnesium and 0.50% to 0.60% silicon, or 0.47% to 0.57% magnesium and 0.75% to 0.85% silicon, and the remainder aluminium except for impurities including iron, copper, manganese, zinc, chromium, and titanium, the aluminium alloy being subjected to ageing treatment at a temperature of not more than 200°C for from 20 to 50 minutes to obtain a 0.2% proof stress greater than 11 kg/mm^2 , an ultimate tensile strength greater than 15 kg/mm^2 and elongation greater than 8%.

The invention also consists, in another of the aspects, in an aluminium alloy shape composed of the alloy in accordance with the invention, the shape being coated over its surface before the ageing treatment with a water soluble paint which is hardened at a temperature of not more than 200°C .

According to yet another aspect of the invention, a method of making an aluminium alloy shape comprises the steps of extrusion forming a cast aluminium alloy in accordance with the invention to obtain an extrusion the cast material consisting, by weight of 0.65% to 0.75% magnesium and 0.50% to 0.60% silicon, or 0.47% to 0.57% magnesium and 0.75% to 0.85% silicon, and the remainder aluminium except for impurities including iron, copper, manganese, zinc, chromium, and titanium, forming an oxide film on the surface of the extrusion, coating the film with paint, and heating the extrusion at a temperature of not more than 200°C for from 20 to 50 minutes to effect curing and hardening of said coated film and simultaneously age hardening of the extrusion.

Some examples of alloys, shapes and methods in accordance with the invention will now be described with reference to the accompanying drawings in which:—

Figure 1 is as already mentioned, a flow chart of a conventional method of making aluminium alloy shapes;

Figure 2 is a flow chart of a method of making aluminium alloy shapes from an alloy in accordance with this invention;

Figures 3 to 6, inclusive, are graphs showing mechanical properties of one example of an aluminium alloy shape in accordance with the invention and one example of a conventional aluminium alloy shape for comparison therewith;

Figure 7 is a front view of a sliding door, which made of an alloy in accordance with the invention, is put to a wind tunnel test;

Figure 8 is a cross-sectional view taken on the line A—A in Figure 7;

Figure 9 is a cross-sectional view taken on the line E—B in Figure 7; and,

Figure 10 is a graph showing the results of the wind tunnel test of the sliding door shown in Figures 7 to 9.

A description will be given first with regard to the composition of the aluminium alloy in accordance with the invention.

(A) An important feature of the alloy in accordance with the present invention lies in the ageing conditions and it is of prime importance that required mechanical properties are obtained with the ageing conditions. In the alloy A.A6063 which is now widely used for construction materials, ageing proceeds when it is heated at $205^{\circ}\text{C} \pm 5^{\circ}\text{C}$ for 60 minutes and optimum mechanical properties are thus obtained. However, in the case where ageing is caused to proceed simultaneously with hardening of a coated film of an inexpensive water soluble paint and the heating time for age hardening is markedly shortened as with the alloy of the present invention, ageing of the alloy proceeds at a temperature of not more than 200°C and a period of time in the range of 20 to 50 minutes.

(B) In alloys in accordance with the present invention, mechanical properties, which are equal to or better than those of conventional aluminium alloys are obtained with the ageing conditions mentioned in (A). Accordingly, the mechanical strength of the alloy A.A6063 (0.2% proof stress 11 kg/mm^2 , ultimate tensile strength 15 kg/mm^2 , elongation 8%) which is regarded as proper, is aimed at. In particular, 0.2% proof stress of 15 kg/mm^2 , ultimate tensile strength of 20 kg/mm^2 and elongation of greater than 8% are aimed values, which are obtainable with the alloy of this invention.

(C) Magnesium forms an intermetallic compound such as Mg_2Si with silicon in aluminium and is deposited in the form of Mg_2Si with a decrease in the solubility of magnesium. With an increase in the amount of Mg_2Si deposited, mechanical strength of the alloy is enhanced and Mg_2Si is deposited through a process of an acicular phase (G.P. Zone)—a bar-shaped phase—a plate shaped phase. However if excessive ageing occurs in this process, Mg_2Si is separated in the plate-shaped phase, the mechanical strength of which is deteriorated as compared with that of the acicular or bar-shaped phase.

To avoid this, the inventors of the present invention studied the range of amount of each of magnesium and silicon in which ageing would be properly achieved under the ageing conditions referred to in (A) and Mg_2Si would be appropriately deposited in the acicular or bar-shaped phase and, as a result of their study, it has been found that when silicon is in the range of 0.50% to 0.60% by weight a proper range of magnesium is 0.65% to 0.75% by weight and that when silicon is in the range of 0.75%

to 0.85% by weight, the proper range of magnesium is 0.47% to 0.57% by weight.

If the silicon content is in the range of 0.50% to 0.60% by weight, with magnesium less than 0.65% by weight, the required strength cannot be obtained and, with magnesium exceeding 0.75% by weight the extrusion property poses a problem.

Further, in the case of silicon in the range of 0.75% to 0.85% by weight, when magnesium is less than 0.47% by weight the age hardening property is rapidly deteriorated. Further, when magnesium is more than 0.57% by weight, if excess silicon is assumed to be present, a problem arises in the extrusion property, too, and the ageing promotional effect by silicon is lost.

Silicon forms the intermetallic compound such as Mg_2Si with magnesium and, at the same time, excess silicon expedites ageing. For example, even under such ageing conditions as a temperature of not more than 200°C and a time of 20 to 50 minutes, age hardening is promoted by silicon. Therefore, silicon is indispensable to this invention. Further, silicon impairs the extrusion property less than magnesium and it might be said to be preferable to increase the amount of silicon added rather than that of magnesium.

Where the amount of magnesium is in the range of 0.47 to 0.57% by weight, this range covers that contained in the conventional alloy A.A6063 but the amount of silicon is greater than in the conventional alloy. Accordingly, in this case, since the amount of magnesium is small, even though a greater amount of silicon is contained, the rate of deterioration of the extrusion property is low, as compared with the case where the amount of magnesium is large. Further, since the amount of magnesium is small, the amount of silicon can be made greater and the mechanical strength can be enhanced to some extent by the effect of adding silicon.

It will be seen that the amounts of magnesium and silicon are related to each other and it is preferred that the amounts of magnesium and silicon are 0.70% to 0.55% by weight respectively or close to these values or 0.52% and 0.80% by weight respectively or close to these values. In these alloys, the required mechanical strength can be obtained by ageing at the lowest temperature in a short time and the adherence of the coated film is also enhanced.

Iron is generally called an impurity element in aluminium alloys and forms for example AlFeSi , Fe_3SiAl_2 , $\text{Fe}_2\text{Si}_2\text{Al}_9$, with aluminium and silicon. These ternary compounds are deposited in the form of relatively large particles in the matrix. Accordingly, a large amount of iron added deteriorates the mechanical strength of an alloy, and hence is not desirable. However, ternary

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compounds of some compositions appropriately roughen the surface of an aluminium alloy shape and are favourable for the formation of an oxide film and the effective bonding of a paint coating over the film. Therefore, the amount of iron is preferred to be in the range of 0.15% to 0.25% by weight.

10 Copper, manganese, zinc, chromium, titanium, and the impurities are mixed in refining and other processes and it is desirable that the amounts of then mixed are as small as possible, preferably less than 0.05% by weight.

15 The aluminium alloy in accordance with this invention having a composition as described in the foregoing and being aged at a temperature below 200°C for 20 to 50 minutes, achieves the required mechanical strength. In the case of shapes of this alloy, 20 the ageing treatment and the coated film printing and hardening treatment can be effected simultaneously, as shown in Figure 2 of the drawings and even if the coated film is of an easily available water soluble 25 paint, it does not become yellowish.

30 A cast billet of an aluminium alloy in accordance with this invention is subjected to homogenization treatment and preheat treatment under usual conditions and is then formed by extrusion, for example, at an extrusion speed of 26 m/min., after which the resulting aluminium alloy shape is subjected to correcting, oxide film forming and 35 coating processes. For the purpose of coating a water soluble thermo-setting paint is satisfactory and, in usual cases, the paint for this purpose may be, for example, of an acrylic system. After the coating process, the aluminium alloy material is heated at a 40 temperature of not more than 200°C for 20 to 50 minutes, by which the coated film is cured and hardened and, at the same time, ageing is properly effected, thus providing an aluminium alloy shape having the mechanical properties mentioned previously in (B).

45 In the above example, the aluminium alloy shape formed of the alloy of the aforementioned composition is not subjected to the ageing process immediately after extrusion forming but, instead, is subjected to the coated film printing and hardening process and the ageing process at the same time. This is because of the fact that omission of the ageing step, indispensable to the conventional method, is preferred from the viewpoints of economy of energy and the intimate adherence of the coated film. Accordingly, the alloy of the aforesaid composition can also be treated by a conventional method. 50 In such a case, extrusion forming is immediately followed by the ageing process but the ageing conditions in this case are a temperature of not more than 200°C and a time of 20 to 50 minutes. Even under such 55 conditions, the mechanical properties referred

to above in (B) can be obtained and, further, since the ageing time is shortened and the ageing temperature is lowered, an economy of energy can be accomplished correspondingly.

70 Further, as described previously, when the ageing process is achieved simultaneously with the coated film printing and hardening process after the surface treatment, a series of processes for extrusion forming, pretreatments such as degreasing and rinsing, oxide film forming, coating and heat treatment for ageing and coated film curing and hardening can be designed as a continuous flow system. Moreover, in the case of simultaneously effecting age hardening and coated film curing and hardening, the aluminium alloy shape is likely to be distorted when it is suspended horizontally, as in the prior art, during such respective treatments as mentioned above and in the final heat treatment, since the aluminium alloy has not yet gained its predetermined mechanical strength. This can be completely avoided by suspending the aluminium alloy shape vertically during such treatments. Further, by subjecting the aluminium alloy shape to all of the aforesaid processes while suspending it vertically, the processes can be easily automated and variations in the coated film can also be reduced.

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Examples of this invention will now be described.

EXAMPLE 1

Billets of two kinds of aluminium alloys *a* and *b* (aluminium alloy *a* contained 0.70% of Mg, 0.55% of Si, 0.20 of Fe, other impurities and the remainder Al, and aluminium alloy *b* contained 0.52% of Mg, 0.80% of Si, 0.20% of Fe, other impurities and the remainder Al) were subjected to homogenisation treatment at 550°C for 3 hours and were preheated at 450°C for 10 minutes and then respective aluminium alloy shapes were formed by extrusion at an extrusion speed of 24 m/min.

110 Thereafter, the respective aluminium alloy shapes were soaked in a 6% NaOH aqueous solution (60°C) for 30 seconds for degreasing and were rinsed with water. Thereafter they were soaked in a 10% HNO₃ aqueous solution (room temperature) for neutralization.

115 Next, the aluminium alloy shapes were anodized in a 15% sulphuric acid aqueous solution to form an aluminium oxide film of 7 to 8 μ thickness as a ground film.

120 Following this, the aluminium alloy shapes were dipped in an acrylic water soluble paint (containing 13.1% of acrylic resin, 6.1% of malamine resin, 22.1% of IPA, 3.4% of Ethylene Glycol Monoethyl Ether and 55.1% water and others) to form a coating film. Then, the aluminium alloy shapes were each heat-treated at different temperatures which were 180°C, 190°C and

200°C, respectively, to harden the paint film and, at the same time, achieve ageing of the alloy. The relationship of the ageing time to the 0.2% proof stress in this example were such as shown in Figure 3.

In Figure 3, solid lines indicate the alloy *a*, dotted lines indicate the alloy (*b*) and broken lines indicate the conventional alloy A.A6063 produced under the same conditions as mentioned above.

The relationships of the ageing temperature to the 0.2% proof stress in the alloy *a*, the alloy *b* and the alloy A.A6063 are such as shown in Figure 4, in which the alloys are indicated by the same lines as in Figure 3, respectively.

Further, the relationships of the ageing time to the ultimate tensile strength and the elongation in the alloys *a*, *b* and A.A6063 are such as shown in Figures 5 and 6, respectively.

In Figures 3 to 6, reference numerals 1 and 2 designate the JIS (Japanese Industrial Standards) level and the A.A. standard level, respectively.

The effects of the alloys *a* and *b* of this invention were ascertained as described above and, at the same time, the adherence of the coated films on the alloys was examined in boiling water and, as a result of this examination, found to be very excellent.

EXAMPLE 2

As in the Example 1, two kinds of shapes formed of a conventional alloy and the alloy (*a*) of this invention, both employed in the Example 1, were heated at 190°C for 30 minutes to effect curing and hardening of coated films and, also, age hardening. Sliding doors such as shown in Figures 7, 8 and 9 were constructed with the above two kinds of aluminium alloy shapes and each of the sliding doors was subjected to a pressure test in a wind tunnel to examine its actual pressure resistance.

A front view of each sliding door put to the test is shown in Figure 7 and its cross-sectional views taken on the line A—A and B—B in Figure 7 are shown in Figures 8 and 9, respectively. The sizes of those parts of the sliding door indicated by reference characters in Figures 7 to 9 are as follows:

W	= 1,360	mm	L	= 1,697	mm
Wa	= 19	"	La	= 25	"
Wb	= 35	"	Lb	= 17	"
Wc	= 21.5	"	Lc	= 26	"
Wd	= 14	"	Ld	= 32	"
We	= 25	"	Le	= 22	"
Wf	= 20	"	Lf	= 17	"
Wg	= 44	"	D	= 60	"
Wh	= 23	"			

In the wind tunnel test, air was blown

against each sliding door from the outside thereof or sucked on the outside thereof at a pressure of 50 kg/m² to 120 kg/m² and deflection at the position of Wg in Figure 7 measured.

The mode of blowing or suction of air was such that pressure of air blown against the sliding door from the outside thereof was taken as positive and that pressure of air sucked on the outside of the sliding door was taken as negative. The positive and negative pressures are indicated by circles and crosses, respectively, in Figure 10, which shows the deflection against wind force.

Considering that sliding doors above the solid line 3 in Figure 10 are accepted ones, the doors formed of the alloy shapes of this invention are all excellent.

As has been described in detail in the foregoing, in the aluminium alloy shapes of this invention, ageing properly proceeds at a temperature of not more than 200°C for 20 to 50 minutes and sufficient mechanical strength can be obtained. Accordingly, even if a water soluble thermal setting type paint is employed, curing and hardening of the coated film and age hardening can be achieved simultaneously. This permits simplification of processes for the manufacture of aluminium alloy shapes and marked reduction of energy consumed therefor. Moreover, as is apparent from a comparison of the ageing conditions of this invention with that of the conventional age hardening aluminium alloy shapes, the ageing temperature is low and the ageing time is appreciably shorter. This also accomplishes an economy of energy.

WHAT WE CLAIM IS:—

1. An aluminium alloy consisting, by weight, of 0.65% to 0.75% magnesium and 0.50% to 0.60% silicon, or 0.47% to 0.57% magnesium and 0.75% to 0.85% silicon, and the remainder aluminium except for impurities including iron, copper, manganese, zinc, chromium and titanium, the aluminium alloy being subjected to ageing treatment at a temperature of not more than 200°C for from 20 to 50 minutes to obtain a 0.2% proof stress greater than 11 kg/mm², an ultimate tensile strength greater than 15 kg/mm² and elongation greater than 8%.

2. An aluminium alloy shape composed of an alloy in accordance with claim 1, the shape being coated over its surface before the ageing treatment with a water soluble paint which is hardened at a temperature of not more than 200°C.

3. A method of making an aluminium alloy shape comprising extrusion forming a cast material to obtain an extrusion, the cast material consisting, by weight, of 0.65% to 0.75% magnesium and 0.50% to 0.60% silicon, or 0.47% to 0.57% magnesium and

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0.75% to 0.85% silicon, and the remainder aluminium except for impurities including iron, copper, manganese, zinc, chromium and titanium, forming an oxide film on the surface 5 of the extrusion, coating the film with paint, and heating the extrusion at a temperature of not more than 200°C for from 20 to 50 minutes to effect curing and hardening of said coated film and simultaneously age 10 hardening of the extrusion.

4. An alloy according to claim 1, in which the iron content is between 0.15% and 0.25% by weight.

5. An alloy shape according to claim 2, in 15 which the iron content of the alloy is between 0.15% and 0.25% by weight.

6. A method according to claim 3, in

which the iron content of the alloy is between 0.15% and 0.25% by weight.

7. An alloy according to claim 1, substantially as described with reference to Example 1 herein. 20

8. An alloy shape according to claim 2, substantially as described with reference to Example 1 herein.

9. A method according to claim 3, substantially as described with reference to Example 1 herein. 25

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FIG. 1

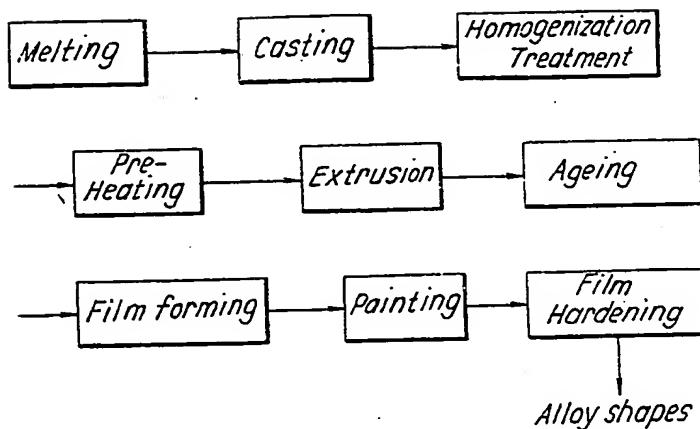
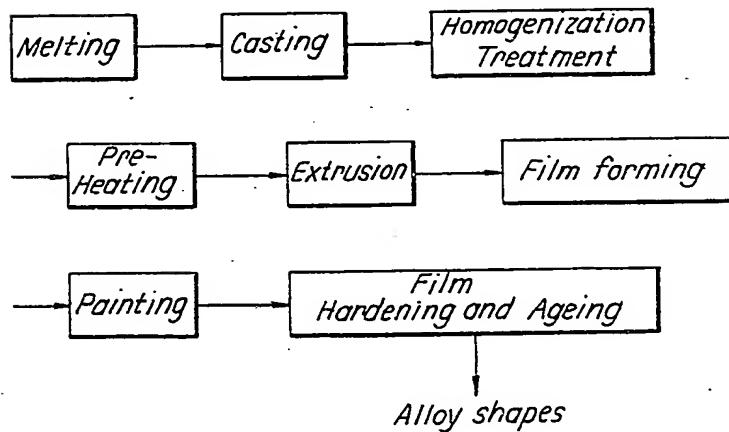


FIG. 2



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FIG. 3

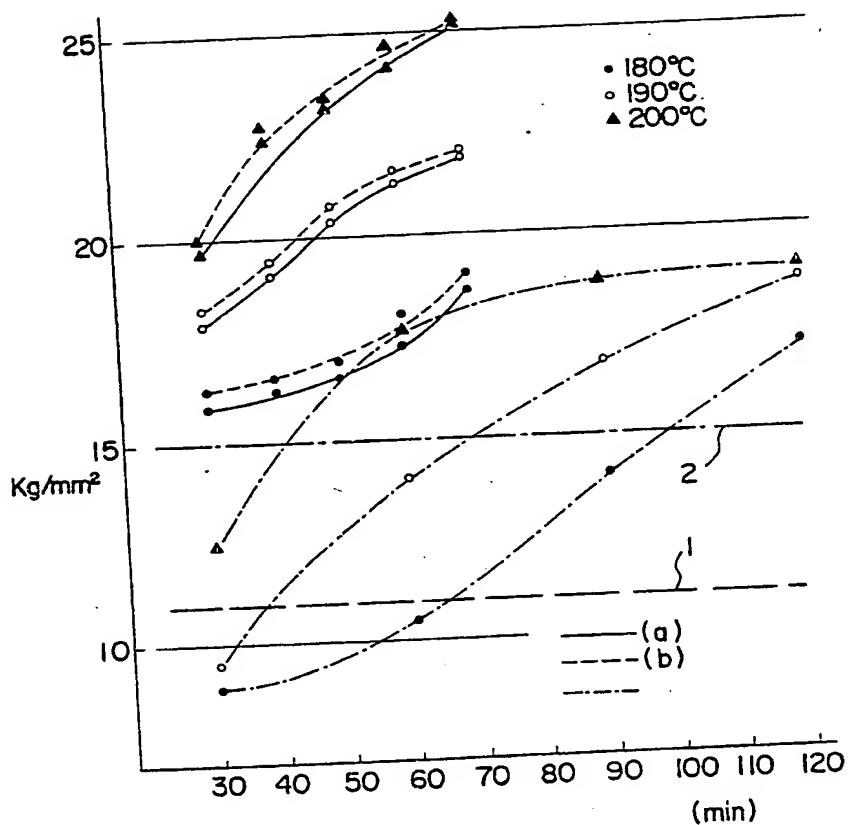
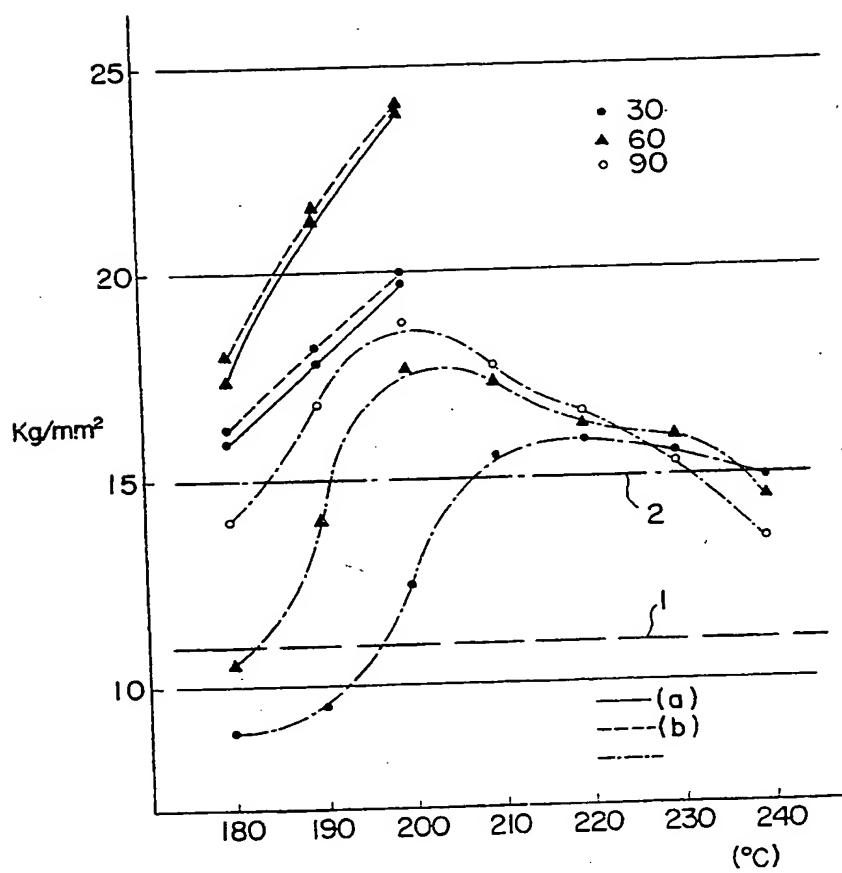


FIG. 4



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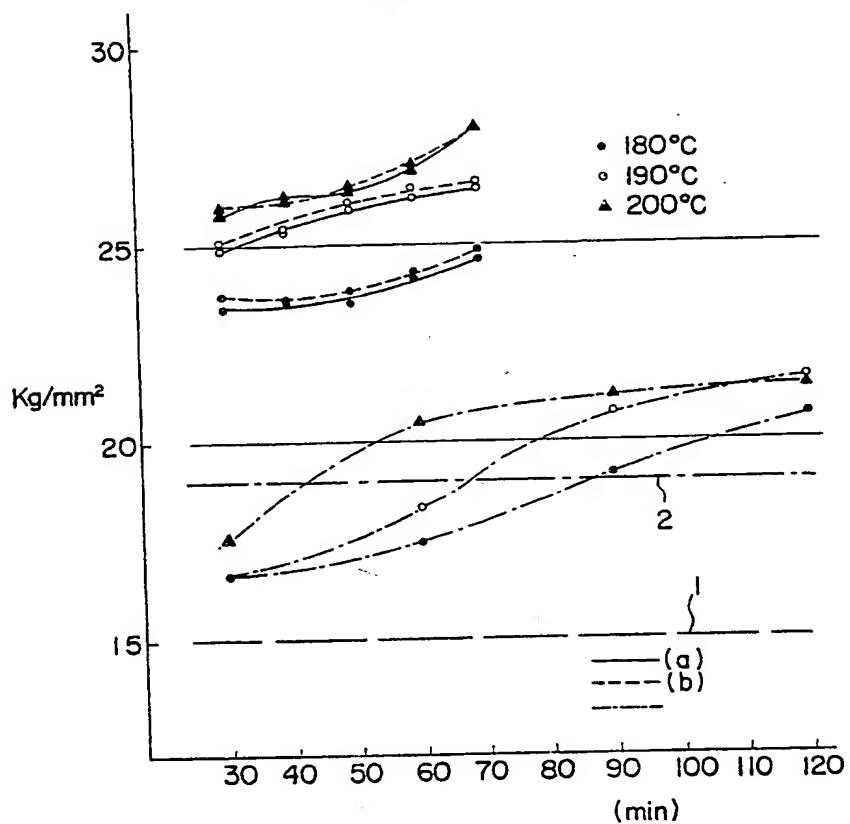
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FIG. 5



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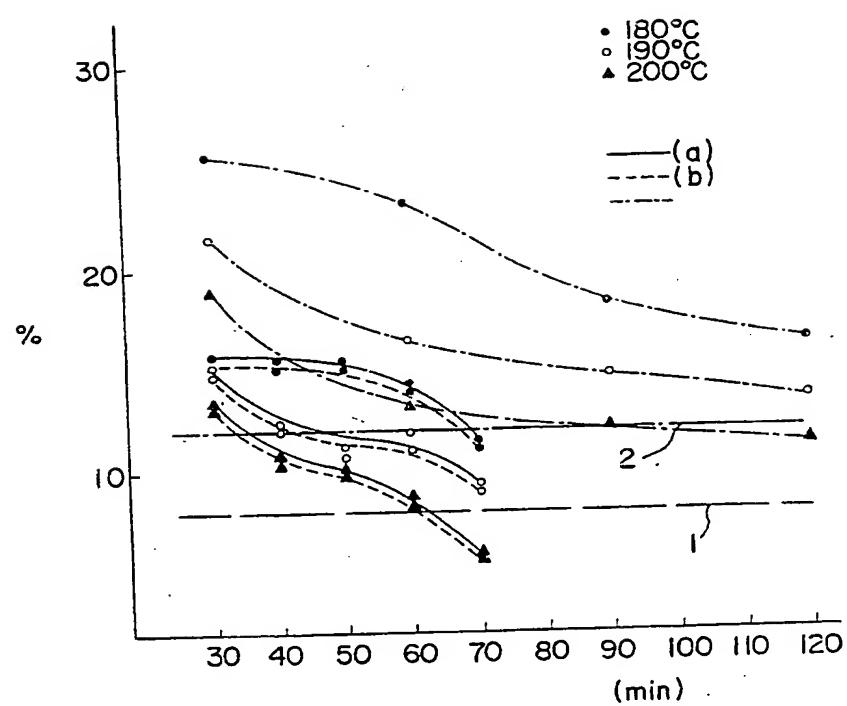
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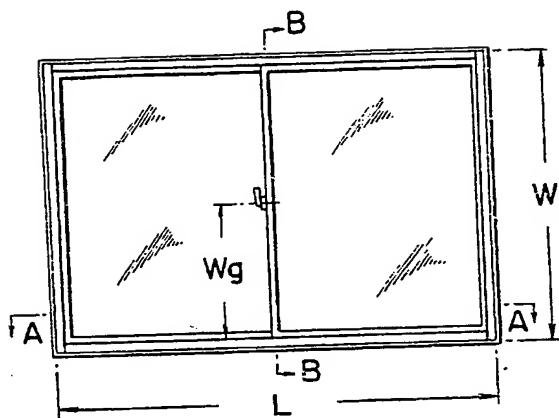
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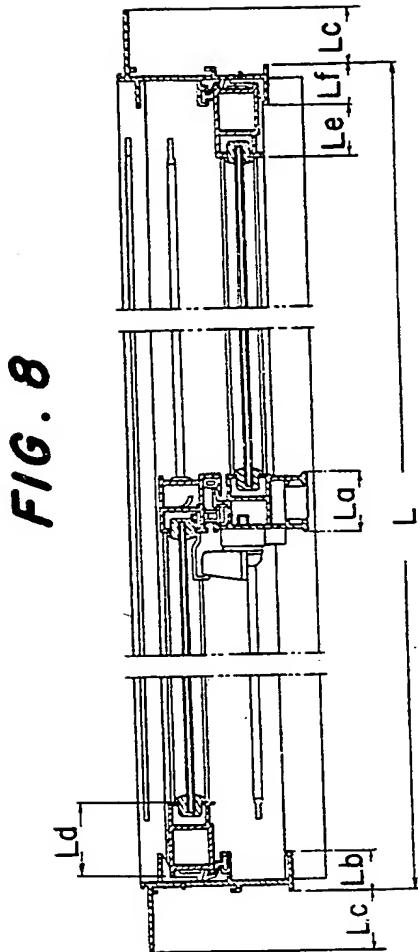
FIG. 6



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FIG. 7





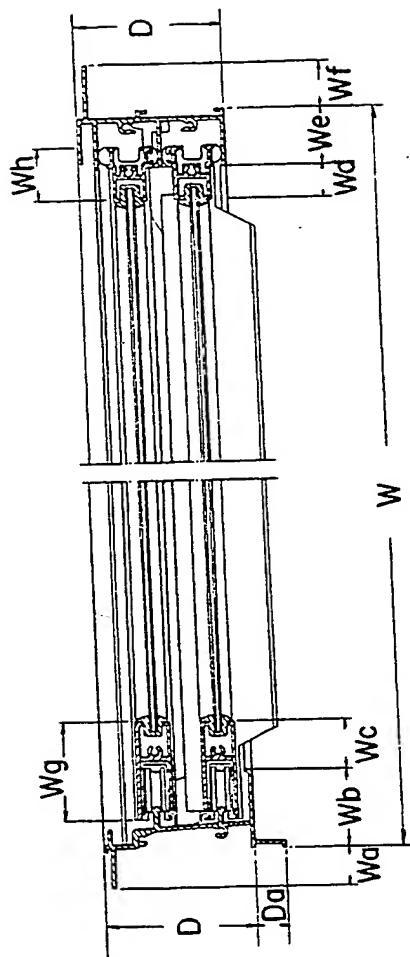
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FIG. 9



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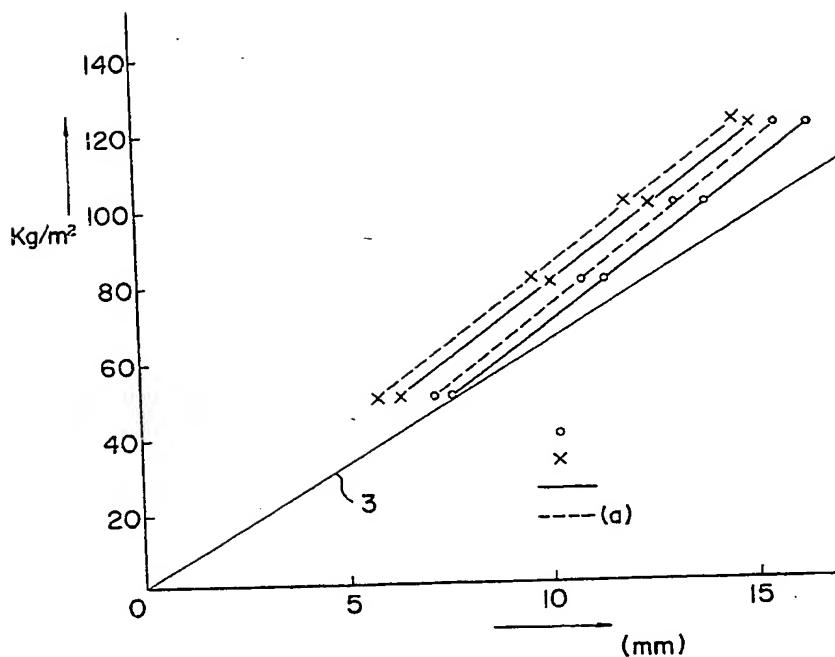
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Fig. 10



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